

Concurrent Systems

Nebenläufige Systeme

I. Introduction

Wolfgang Schröder-Preikschat

October 14, 2015



Agenda

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Summary



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Abstract Concept

- meaning of the lecture labelling in linguistic terms [3]:
con·cur·rent (lat.) *concurrrens*: preposition of *concurrere*

sys·tems plural of (gr.) *systemas*: to place together



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con·cur·rent (lat.) *concurrans*: preposition of *concurrere*
 1. occurring at the same time; existing together
 2. meeting in or going toward the same point; converging
 3. acting together; cooperating
 4. in agreement; harmonious
 5. exercised equally over the same area



- meaning of the lecture labelling in linguistic terms [3]:

sys-tems plural of (gr.) *systemas*: to place together

1. a set of arrangements of things so related or connected as to form a unity or organic whole
2. a set of facts, principles, rules, etc. classified or arranged in a regularly, orderly form so as to show a logical plan linking the various parts
3. a method or plan of classification or arrangement
- ⋮



- in terms of computer science: a system of several computations who are executing simultaneously, potentially interacting with each other



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Concurrency as a System Property

- **simultaneous execution** of potentially interacting computations
 - with the latter being logical (cooperating) or contending (incidental)

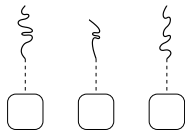


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multiplication of processing units

- real parallelism
- instruction set architecture level
- partitioning in space



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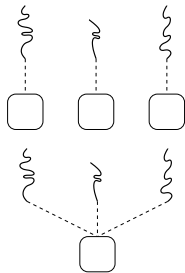
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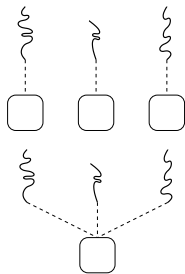
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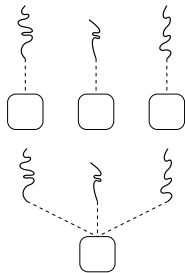
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 - however, each of the two “concurrency dimensions” originates in different functions to coordinate/synchronise concurrent processes
- focus is on **parallel processing** of the same **non-sequential program**



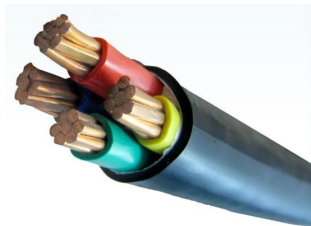








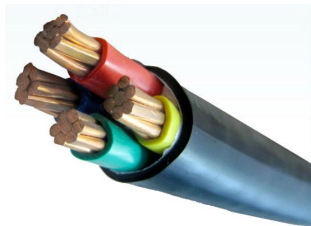
- parallel-computer engineering is pervasive
 - **multi-core** ■ conventional characteristic
 - **uni-core** ■ rather unconventional, but rife
- by the way: multi-core \subset many-core
 - **multi** ■ little tens (“handful”) of cores
 - **many** ■ several tens of cores and more
 - hundreds or even thousands
- exposure to parallelism is indispensable [4]
 - mandatory at least for operating systems



28 **cores**, uniformly distributed across four **tiles** 😊



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- many-core processors make **core multiplexing** almost superfluous
 - unless **latency hiding** becomes an issue within a parallel process



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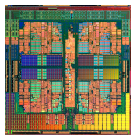
2 cores



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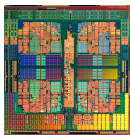
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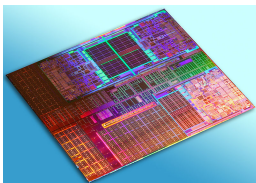
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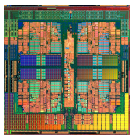
8 cores



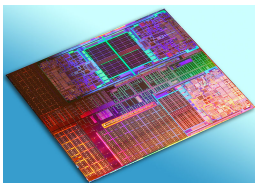
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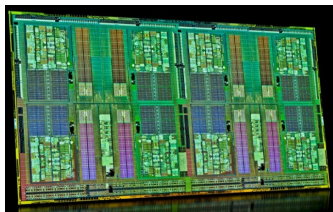
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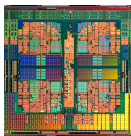
16 cores



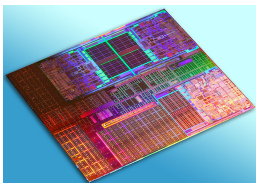
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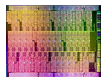
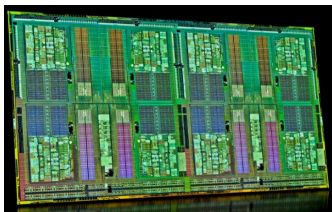
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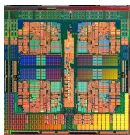
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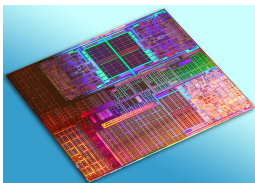
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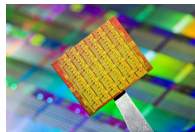
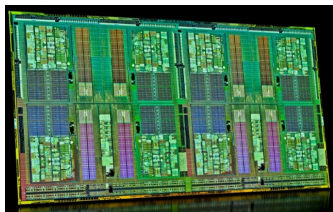
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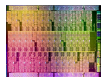
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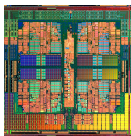
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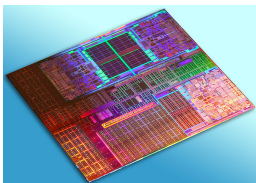
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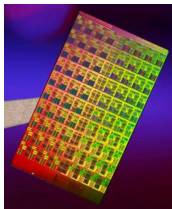
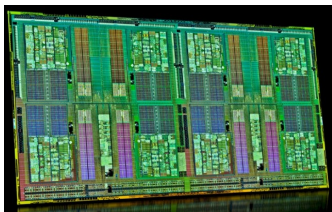
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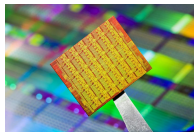
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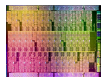
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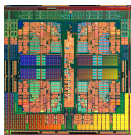
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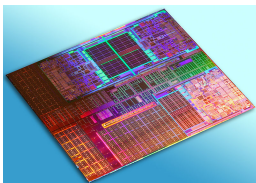
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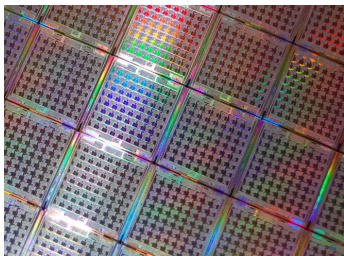
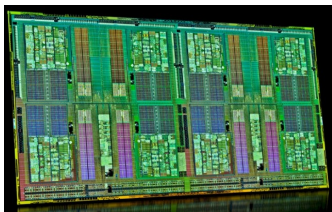
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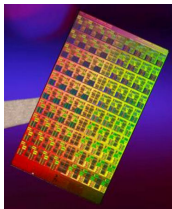
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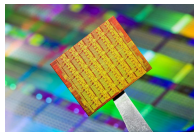
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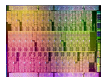
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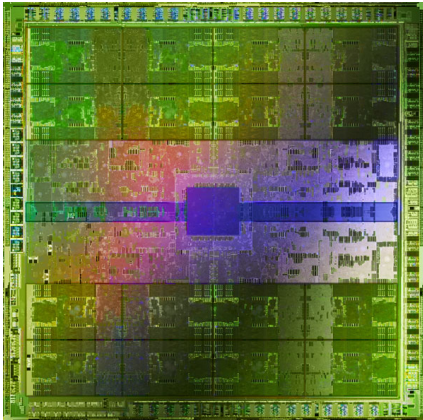


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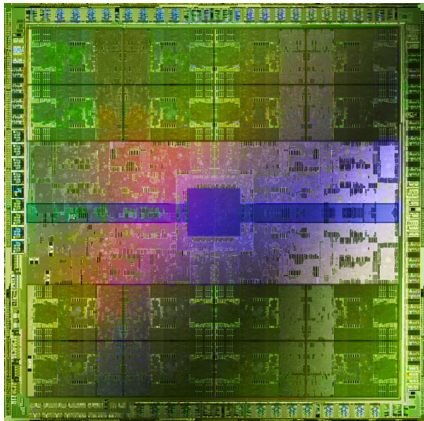
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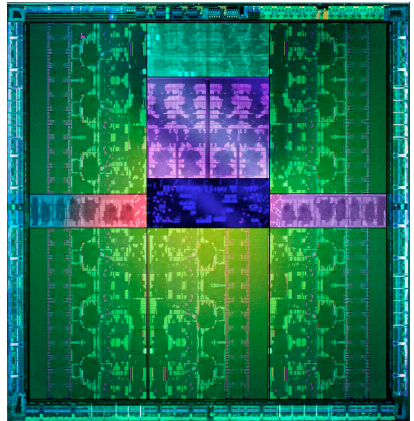


512 cores



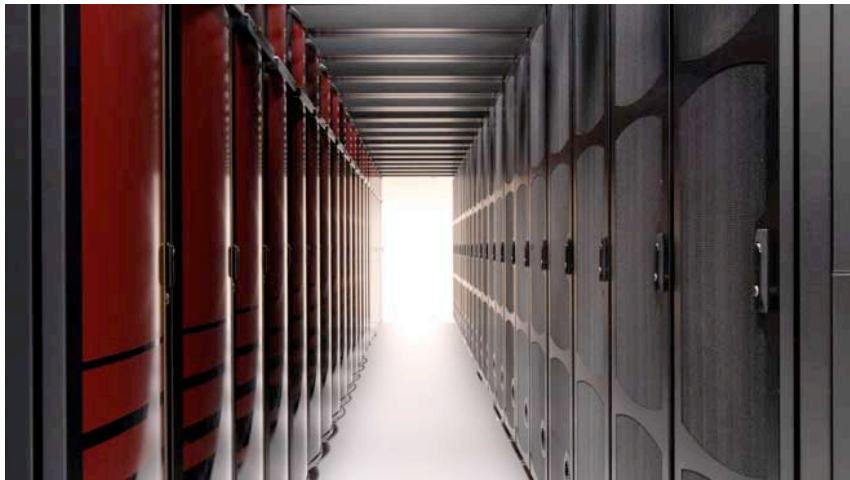


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1536 cores





3 120 000 cores



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- address-space **organisation**
- cache **coherency**: memory *property*
- memory (also: cache) **consistency**: memory *state*



- **nature** of the overall processor architecture
 - homogeneous
 - in functional terms: instruction set architecture (ISA)
 - but also non-functional: latency, clock speed, energy use
 - heterogeneous
 - different in at least one of those aspects



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 - shared** ■ globally direct memory access: load/store operations
 - maybe partitioned global address space (PGAS)
 - distributed** ■ globally indirect memory access: message passing



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 - temporary (memory/cache) inconsistencies are tolerated
 - non-coherent
 - else



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 - sequential, processor, weak, entry, or release consistency



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1. overview, organisation—today's lecture. . .



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General topics and basic principles:

2. notion of “concurrency” against the background of resource sharing
 - causality (“cause and effect”), synchronisation, indivisibility
3. notion of “process” and difference to “program”
 - sequential, non-sequential, concurrent, interacting
4. critical (program) sections and their typical patterns
 - race conditions/hazards: lost update, lost wakeup
5. elementary operations and other hardware aspects
 - TAS, CAS, and LL/SC versus caches, coherence, and interference



Classic and folklore:

6. lock algorithms
 - contention, backoff, ticket, interference
7. semaphore
 - binary (vs. “mutex”), general/counting, bolt, set
8. monitor and condition variable
 - signalling semantics: Hansen, Hoare, Mesa, Java
9. deadlock and livelock
 - prevention, avoidance and detection & resolution



Avant-garde and other:

10. algorithms based on indivisible memory-write instructions
 - assuming vertical (stack-like) overlapping
 - interrupt-transparent synchronisation
11. algorithms based on dedicated machine instructions
 - assuming horizontal (congeneric) overlapping
 - compare and swap (CAS), load linked (LL) and store conditional (SC)
12. transactional memory
 - AMD's advanced synchronisation facility (ASF)
 - Intel's transactional synchronisation extensions (TSX)
13. progress guarantees
 - obstruction-, lock- and wait-free behaviour
 - constructive (favoured) and analytical (neglected) approaches



State of the art and recapitulation:

14. right from the rummage table. . .
 - software combining, procedure chaining, combining funnels
 - read-copy update, remote-core locking
15. wrap-up and words in a personal matter
 - retrospection and lessons learned
 - research projects on these topics at the chair
 - perspectives for advanced training: bachelor, master, doctoral thesis



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Hint (Lecture)

*Main objective is to impart knowledge on concurrent systems from the **system programming point of view**. Wide emphasis is on the internals of synchronisation concepts and primitives as well as the implications of the respective implementations. Application of these methods for parallel programming takes a back seat.*



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 - German
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 - will be asked for at the beginning of each lesson
 - English
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¹Studying abroad also means *living* abroad—and to take part and share in Franconian social life. The latter *soft skills* cannot be overestimated.





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- written material (slides or handouts, resp.) will be English
 - with technical terms also stated in German, where applicable

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- acquire new knowledge
- relate it with previous knowledges



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 - prepare next reading on ones own initiative
 - attend presentation, listen, and discuss topics treated
 - reinforce learning matter, reflect



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 - computer architecture (GRA) 13
 - system programming (SP, SPiC, GSPiC) 14
 - operating systems (BS), operating-systems engineering (BST) 14
 - real-time systems (EVS) 14



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- teaching material presented in the **lecture room**:
 - follow “Lehre” (Eng. *teaching*) at <https://www4.cs.fau.de>
 - copies of the slides are made available as handouts free of charge
 - supplemented by secondary literature as and when required
 - see the bibliography at the bottom of each handout



- deepen knowledge by means of direct experience

Acquisition of virtuous behaviour and operational ability is less a matter of easy instruction but rather functional copy, practise, and use. (Aristotle [1])



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 - registration through [WAFFEL](#)² (URL see CS web page)
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- **computer work** under individual responsibility
 - registration is not scheduled, reserved workplaces are available
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 - mandatory
 - structured computer organisation
 - algorithm design and development
 - principles of programming in C or C++
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- **soft** (personal, social, methodical) **skills**
 - staying power, capacity of teamwork, structured problem solving



Major Course Assessment

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 - 5 ECTS (*European Credit Transfer System*)



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 - date by arrangement: send e-mail to wosch@cs.fau.de
 - propose desired date within the official audit period
 - the exception (from this very period) proves the rule...

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 - brought up in the manner of an “expert talk”
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Subject Matter

- coordination of cooperation and concurrency
 - between interacting (i.e., control- or data-flow dependent) processes
 - with emphasis on explicit synchronisation
- against the background of two dimensions of concurrency
 - vertical
 - overlapped execution at operating-system machine level
 - process preemption (partial virtualisation)
 - horizontal
 - overlapped execution at instruction set architecture level
 - processor (core) multiplication
- in-depth study of approaches suitable (not only) for operating systems
 - advanced studies to the range of topics on system programming
 - basic studies to concurrent (i.e., non sequential) programming
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